Rapport d'activité

Etude de la génération de séismes et la propagation des ondes sismique
- Study on the earthquake generation and seismic wave propagation processes -

1. General Information

Projet : A0110406700
Responsable : AOCHI Hideo

Allocation
TGCC BULL Joliot Curie/Irene Rome : 240 000 heurs scalaires
(CINES BULL nœuds fins Occigen : 82 800 heures scalaires, bonus en 2021)

Consommation
TGCC BULL Joliot Curie/Irene Rome : 260 606 heures scalaires (16/08/2022), soit 108.59 % des heures accordées.
(CINES BULL nœuds fins Occigen : 82 800 heures scalaires, soit 100 % des heures accordées)

2. Scientific Results (below is written in English)

We began to configure Boundary Domain Method (BDM), a hybrid method combining boundary integral equation and finite difference methods. The main targets were reverse faults such as the 2019 Mw4.9 Le Teil, France, earthquake. Physical questions are always raised on the initial and boundary conditions, namely initial stress field and frictional parameters along the causal faults. In parallel, we have developed a theoretical concept of strain-constrained depth-dependent stress According to the idea previously presented in Aochi & Tsuda (EGU, 2021), we realize certain numbers of simulations, particularly in order to reply to the question why the earthquake rupture is limited at certain depths with and without surface rupture. The works are summarized in a paper. Although the initial submission of a short paper to GRL was not successful in the late 2021 (disagreed with one reviewer), the full paper to GJI was submitted in February 2022 and revised in July 2022 (**Aochi & Tsuda, in revision GJI, 2022**).

We are extending this work to discuss the variation of ground motions in the near field. **Figure 1** shows two simulation examples for a type of the M4.9 Le Teil earthquake. The left panel shows the case of the initial stress field constrained by layered structure (**Aochi & Tsuda, in revision GJI, 2022**), while the right one is the case of the initial stress field is uniformly loaded at all the depth (except at depth). In the former case, the rupture propagates laterally first at depth and arrives gradually on the ground surface. On the other hand, in the latter case (often proposed), the rupture propagates directly along the fault dip and then propagates laterally. Consequently, the ground motions are significantly influenced. **Figure 2** compares the two models. It is very significant that the latter model (red marks) gives a very strong directivity effect (A pulse with a very big amplitude) of the rupture progress. However such pulses are less visible in the other case (blue marks). Interestingly, such variation of the ground motions can be statistically confirmed. For the randomly distributed receiver points, we plot the Peak Ground Velocity comparing to the empirical relation from Boore and Atkinson model. Our newly proposed stress field provides a better fitting to the model and the variation is also closer to the empirical law. This is partially presented in **Aochi and Tsuda (EGU, 2022)** and will be presented further in **Aochi et al. (SSJ, 2022)**.

On the other hand, we attempted to model the ground oscillations during the 2018 Greenland landslide and tsunami event (equivalent magnitude of M4.8 in GFZ catalog). Tsunami generation and propagation was simulated by Kyoto University, Japan and this model was implemented in our finite difference code. The model area is about 65 km x 45 km x 10 km for a duration of 900 seconds (15 mins). Our sequential simulation of landslide-tsunami-elastodynamics distinguishes different radiations of the seismic waves at NUUG station (**Figure 3**). The numerical simulations show that the ground motions from the landslide attenuate quickly in space and time, while the ones accompanied by tsunami propagation attenuate gradually, namely peak ground velocity attenuates with 1/sqrt(r), where r is the distance from the origin. According to a synthetic case study, NUUG station (a few hundred meters from the coast) is sensible to the water level change within 2 km off the coast line. Our numerical test indicates that seismic station near the coast line can be used for monitoring the on-going tsunamis propagation. This result is going to be presented this autumn (**Aochi et al., SSJ, 2022b**).

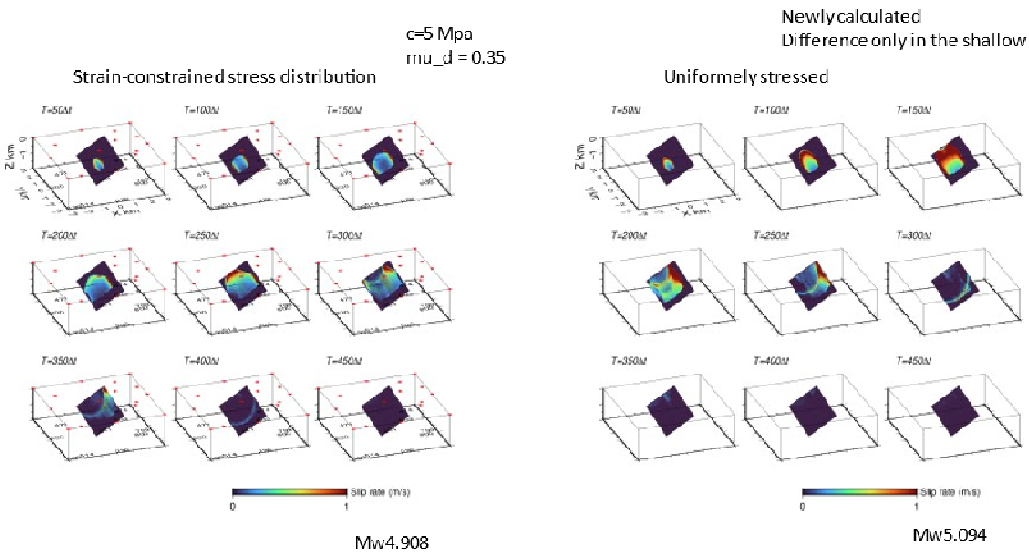

*Figure 1: Snapshot of dynamic rupture simulations of a reverse fault of a moderate magnitude (M~5). The left panel shows the case where the initial stress along fault dip is assumed according to the layered structure after **Aochi and Tsuda** (**in revision GJI, 2022**). The right panel shows the case where the initial stress is uniformly loaded at any depths. Spatial grid of 25 m and a time step of 0.0005 s.*

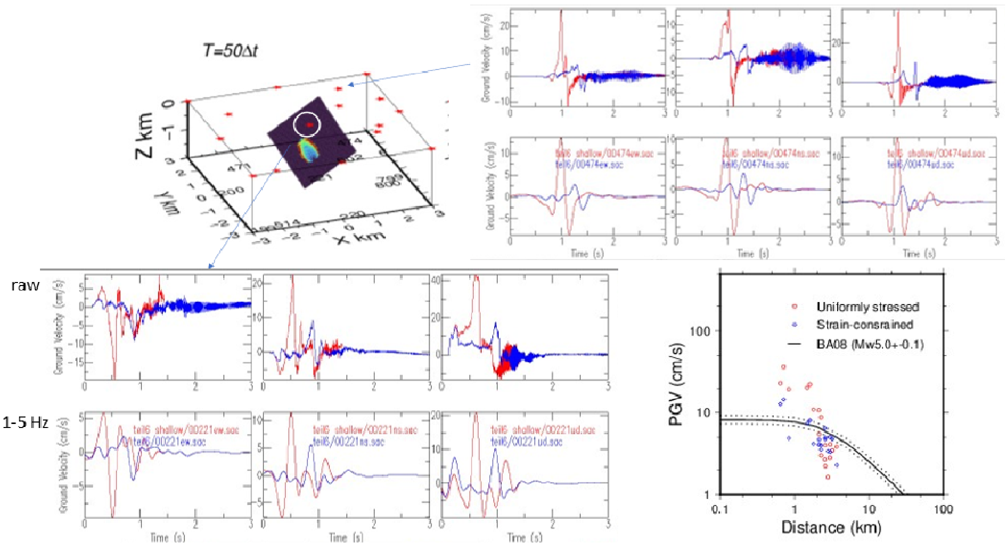

Figure 2: Comparison of ground motions at two stations. Blue and red colors represent the two cases, heterogeneously loaded model according to the layer's structure and the case uniformly loaded at any depths. The top and below windows show respectively the velocity ground motion without and with filter between 1-5Hz, in the EW, NS and UD components from left to right. Peak Ground Velocity (PGV) is compared with the known attenuation law (Boore and Atkinson 2008) model. Presented as ***Aochi et al. (SSJ, 2022a)****.*

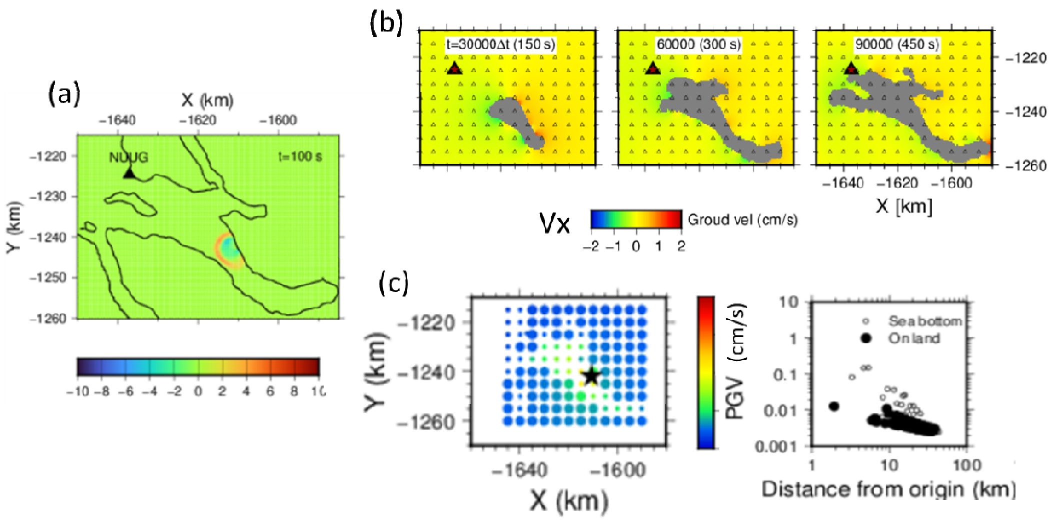

Figure 3: (a) A snapshot of landslide-tsunami simulation at time 100 s. NUUG station is about 30 km away from the origin of landslide and tsunami. The simulations are carried out through the collaborations with Kyoto University. (b) This scenario is coupled with finite difference method of elastodynamics, running on the GENCI ressource (c) The peak ground velocity in space and in function of distance from the origin, for 2D horizontal components and 3D vectorial component, respectively. The star shows the position of tsunami generation, from which the distance is calculated. The solid big circles show the positions on land, while the others are at the sea bottom. (After ***Aochi et al., SSJ, 2022b****)*

3. Publications submitted or in preparation

Aochi, H. & K. Tsuda, Dynamic rupture simulations based on depth-dependent stress accumulation, Geophysical Journal International, July 2022. (original submitted in February 2022).

Aochi, H., K. Tsuda, & S. Yoshida, Impact of rupture behavior in the shallowest part of fault on the near-field ground motions, in preparation, 2022.

4. Conferences and posters

Aochi, H. & K. Tsuda, Numerical simulation of dynamic rupture and ground motion on a fault non-uniformly loaded along dip, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-1672, https://doi.org/10.5194/egusphere-egu22-1672, 2022.

Aochi, H. & S. Ruiz, Earthquake scaling from dynamic rupture simulations, International Joint Workshop on Slow-to-Fast Earthquakes 2022, Nara, Japan, 14-16 September 2022.

Aochi, H., K. Tsuda, & S. Yoshida, Near-Field Ground Motion Simulation based on Depth-Dependent Stress Accumulation Model I, Interpretation of the 2019 Mw4.9 Le Teil earthquake, Seismological Society of Japan Fall Meeting, Sapporo, Japan, 24-26 October 2022a.

Aochi, H., M. Yamada, & T.-C. Ho, Ground oscillations generated by the passage of Tsunamis : Observations and numerical simulations, Seismological Society of Japan Fall Meeting, Sapporo, Japan, 24-26 October 2022b.